

AN INTEGRATED RARE EARTH ELEMENTS SUPPLY CHAIN STRATEGY

BY

COLONEL KARL BOPP
United States Army

DISTRIBUTION STATEMENT A:

Approved for Public Release.
Distribution is Unlimited.

USAWC CLASS OF 2011

This SRP is submitted in partial fulfillment of the requirements of the Master of Strategic Studies Degree. The views expressed in this student academic research paper are those of the author and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government.



U.S. Army War College, Carlisle Barracks, PA 17013-5050

The U.S. Army War College is accredited by the Commission on Higher Education of the Middle State Association of Colleges and Schools, 3624 Market Street, Philadelphia, PA 19104, (215) 662-5606. The Commission on Higher Education is an institutional accrediting agency recognized by the U.S. Secretary of Education and the Council for Higher Education Accreditation.

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YYYY) 24-02-2011		2. REPORT TYPE Strategy Research Project		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE An Integrated Rare Earth Elements Supply Chain Strategy				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) COL Karl Bopp				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Professor Bernard F. Griffard Center for Strategic Leadership				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army War College 122 Forbes Avenue Carlisle, PA 17013				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Distribution A: Unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Rare earth element (REE) materials—rare earth ores, oxides, metals, alloys, semi-finished rare earth products, and components containing REEs are used in a variety of commercial and military applications, such as cell phones, computer hard drives, and Department of Defense (DoD) precision-guided munitions. Today, most rare earth materials processing is performed in China, giving it a dominant position that could affect worldwide supply and prices. A disruption or manipulation of the rare earth elements supply chain will negatively impact DoD's National Security mission. To mitigate this vulnerability, DoD needs an integrated rare earth elements supply chain strategy that addresses the vulnerabilities and competing interests in such an integrated supply chain strategy.					
15. SUBJECT TERMS Rare Earth Elements, Rare Earth, REE					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UNLIMITED	18. NUMBER OF PAGES 32	19a. NAME OF RESPONSIBLE PERSON
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED			19b. TELEPHONE NUMBER (include area code)

USAWC STRATEGY RESEARCH PROJECT

AN INTEGRATED RARE EARTH ELEMENTS SUPPLY CHAIN STRATEGY

by

Colonel Karl Bopp
United States Army

Professor Bernard F. Griffard
Project Adviser

This SRP is submitted in partial fulfillment of the requirements of the Master of Strategic Studies Degree. The U.S. Army War College is accredited by the Commission on Higher Education of the Middle States Association of Colleges and Schools, 3624 Market Street, Philadelphia, PA 19104, (215) 662-5606. The Commission on Higher Education is an institutional accrediting agency recognized by the U.S. Secretary of Education and the Council for Higher Education Accreditation.

The views expressed in this student academic research paper are those of the author and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government.

U.S. Army War College
CARLISLE BARRACKS, PENNSYLVANIA 17013

ABSTRACT

AUTHOR: COL Karl Bopp

TITLE: An Integrated Rare Earth Elements Supply Chain Strategy

DATE: 24 February 2011 **WORD COUNT:** 5,709 **PAGES:** 32

KEY TERMS: Rare Earth Elements, Rare Earth, REE

CLASSIFICATION: Unclassified

Rare earth element (REE) materials—rare earth ores, oxides, metals, alloys, semi-finished rare earth products, and components containing REEs are used in a variety of commercial and military applications, such as cell phones, computer hard drives, and Department of Defense (DoD) precision-guided munitions. Today, most rare earth materials processing is performed in China, giving it a dominant position that could affect worldwide supply and prices. A disruption or manipulation of the rare earth elements supply chain will negatively impact DoD's National Security mission. To mitigate this vulnerability, DoD needs an integrated rare earth elements supply chain strategy that addresses the vulnerabilities and competing interests in such an integrated supply chain strategy.

AN INTEGRATED RARE EARTH ELEMENTS SUPPLY CHAIN STRATEGY

Disruption in the global supply of rare earths poses a significant concern for America's energy security and clean energy objectives, its future defense needs, and its long-term global competitiveness.

— Mark A. Smith CEO Molycorp Minerals
Testimony to House Science and Technology Committee, March 2010¹

Rare earth element (REE) materials — ores, oxides, metals, alloys, semi-finished products and components containing REEs are used in a variety of commercial and military applications, to include cell phones, computer hard drives, hybrid cars and Department of Defense (DoD) precision-guided munitions and aircraft. Most REE processing is currently performed in China, giving it a dominant position that could affect worldwide supply and prices.² The National Defense Authorization Act of 2011 directs the Secretary of Defense to conduct an immediate review of DoD rare earth requirements and establish an “assured source of supply” for rare earth material by 2015.³

The criticality of REE based applications, coupled with China's dominance of the global supply chain, raises several strategic questions: Is DoD's National Security mission vulnerable to a disruption or manipulation of the global REE supply chain? What strategy could DoD employ to reduce the vulnerability of a supply chain disruption or manipulation? What other national interests must be considered when developing a strategy to mitigate a REE supply chain vulnerability?

A disruption or manipulation of the global REE supply chain would negatively impact DoD's National Security mission. To mitigate this vulnerability, DoD should

employ a strategy that promotes development of an integrated REE supply chain ensuring it's' industry and technology bases are sufficient, stable and cost efficient. Such an initiative leverages public and private sector ingenuity to secure our supply chains and supports development of clean technology to enhance economic prosperity, as described in the 2010 National Security Strategy.⁴ It also supports the U.S. mineral policy goal of promoting an adequate, stable and reliable supply of materials for national security, economic well being and industrial production.⁵

Rare Earth Elements.

Rare earth elements are 17 chemically similar metallic elements identified as atomic numbers 21, 39 and 57-71 on the periodic table. Rare earth elements are further classified as “light” or “heavy” based on their atomic weight. Elements with atomic numbers 57-63 are considered light while 39 and 64-71 are considered heavy. Rare earth elements must be separated from other minerals as they do not occur in their elemental state.⁶

Rare Earth Element Applications. Rare earth elements are useful for a variety of applications as many possess unique mechanical, magnetic or spectral characteristics. Examples include: yttrium's extremely high affinity for oxygen makes it useful for many lighting applications to include computer displays, erbium's extremely narrow absorption band makes it useful for fiber optic and laser applications, and, samarium based magnets have the highest resistance to demagnetization known.⁷ Table one highlights select applications by element.

Rare earth element applications permeate industry however because rare earth material is usually far upstream in the supply chain, typically only industry experts understand their significance.⁸ The 2008 REEs end use percentages highlight their

diversity and criticality: metallurgical applications and alloys, 29%; electronics, 18%; phosphors for computer monitors, lighting, radar, televisions and X-ray film, 12%; chemical catalysts, 14%; automotive catalytic converters, 9%; glass polishing and ceramics, 6%; permanent magnets, 5%; petroleum catalysts 4%; other, 3%.⁹

Element	Atomic #	Select applications and uses
Scandium	21	ceramics, lasers, phosphors
Yttrium	39	ceramics, computer displays, fluorescent lighting
Lanthanum	57	hydrogen batteries, catalysts
Cerium	58	glass polishers, ceramics, phosphors
Praseodymium	59	ceramics
Neodymium	60	magnets, lasers, glass coloring
Promethium	61	
Samarium	62	magnets, lasers, electric components
Europium	63	computer screens, fluorescent lights
Gadolinium	64	magnetic applications, phosphors
Terbium	65	phosphors, projection TV's
Dysprosium	66	magnets
Holmium	67	lasers, magnets
Erbium	68	lasers, fiber optics
Thulium	69	crystals, lasers
Ytterbium	70	fiber optics, lasers
Lutetium	71	x-ray phosphors

Table 1. Rare Earth Element Applications.¹⁰

Rare earth elements based applications are critical to many technically advanced U.S. military weapons and systems. Some examples include: samarium-cobalt magnet motors and actuators in multiple guided missiles; neodymium-iron boron magnets in Joint Direct Attack Munitions (JDAM) smart bombs; neodymium-yttrium-aluminum-garnet lasers and range finders in multiple weapon systems to include the M1A1/2 main battle tanks; yttrium stabilized zirconia heat resistant coating applied on high

performance aircraft to include the F15 and F16; rare earth based magnets in satellite wave guides; Terfonal-D, a REE alloy, in state of the art ship and submarine sonar; cerium based polishers used for multiple military optics; yttrium based magnets in phase shifters, tuners and filters for the PATRIOT air defense missile system; and, gadolium, yttrium and samarium based components in electronic countermeasure equipment.¹¹

In addition, rare earths are essential for several green technologies to include: hybrid and electric car batteries (lanthanum), fluorescent phosphors (terbium) for energy efficient lights and magnet generators (samarium and neodymium) for new generation wind turbines.¹² A critical component of next generation wind turbines is the rare earth based magnet generator, which is 70% more efficient and reliable than the current industry standard.¹³

China attributes much of the U.S.'s success in the first Gulf War to REE based technology and initiated significant R&D investment in the 1990s. Today, China has significantly more scientists and technicians conducting REE R&D than the United States. Cindy Hurst, a research analyst at the Fort Leavenworth Foreign Militaries Study Office, states "Most press reports today express concern about the supply and demand of REEs and China's tightening supplies... Yet there is little mention made regarding China's research and development efforts, which probably deserve the most attention since research and development is the driving force behind China's success."¹⁴

REE Alternatives. Alternatives to many rare earth applications are available, but in general provide reduced performance.¹⁵ Defense officials acknowledge REE based applications for military equipment would be difficult to replace.¹⁶ Development of

alternative applications is a long term endeavor requiring sustained funding and commitment. A 2010 GAO report advises an alternative application could take up to 15 years to develop.¹⁷

Global Supply. Rare earth element bearing material is found globally and reserves are projected to meet expected demand thru the 21st century (table 2).¹⁸ Chemical metallurgy expert, Dr. C.K. Gupta, defines REE reserves as “the specific bodies of rare earth element bearing material of known location, quality and quantity, from which the rare earth can be extracted presently.”¹⁹ Specific reserves vary for each REE, and there are fewer reserves of the heavy elements.²⁰ China has the most reserves and is the world’s largest supplier of heavy and light REEs.²¹

	Reserves	Mine Production	
		2008	2009
United States	13,000,000	0	0
Australia	5,400,000	0	0
Brazil	48,000	650	650
China	36,000,000	120,000	120,000
Commonwealth of Ind. States	19,000,000	NA	NA
India	3,100,000	2,700	2,700
Malaysia	30,000	380	380
Other Countries	22,000,000	NA	NA
World Total	99,000,000	124,000	124,000

Table 2. Global Rare Earth Reserves and Mine Production (metric tons).²²

Many deposits contain several REE bearing minerals, making extraction complex and less cost effective. Reserves currently being exploited primarily come from deposits of a single REE bearing mineral such as bastnasite or monazite. Significant bastnasite deposits are located in Mountain Pass, California and Banyan Obo, China. Significant monazite deposits are located in South Africa, China and Australia.²³

Recycling REE material from scrap applications is not considered a significant source of supply.²⁴ The U.S. does not possess the capability to reclaim rare earth based military or consumer applications.²⁵

Global Demand. World-wide consumption of rare earth elements is currently 134k metric tons and demand is projected to climb to 180k metric tons by 2012 due to projected growth in sectors using REEs.²⁶ China, the world's largest REE material supplier, projects its' demand to outpace production by 2012. Projected sector growth includes green technology which is expected to increase as the U.S. seeks energy security through renewable sources.²⁷ Dudley Kingsnorth, executive director of the Industrial Minerals Company of Australia foresees potential shortages of heavy REEs by 2015 due to increased green technology demand.²⁸ Keith Bradsher of the New York Times stated in a December 2009 article the heavy rare earths dysprosium and terbium are already in short supply due to the increase of green technology applications.²⁹

Increased demand is also a function of the significant volume of rare earth material required for some green technology applications. As an example, production of a magnet generator for a new generation wind turbine requires up to two tons of neodymium. Mark Smith, the CEO for Molycorp Minerals, testified this quantify of material for a single application was previously unheard of in the REE industry where demand was typically measured in pounds or kilograms.³⁰

The Rare Earth Element Supply Chain.

The rare earth element processing supply chain consists of: (1) mining rare earth ore (2) separating the rare earth ore into oxides (3) refining the oxides into metals (4) forming the metals into alloys and (5) manufacturing the alloys into applications. While

the U.S. exports some ores and alloys, China currently dominates all levels of the global supply chain.³¹

Mining. China accounted for 97% of REE global mining production in 2009 while no REE mining was conducted in the U.S. (Table 2).³² As a result of Chinese production, enabled by low-cost labor and lax environmental regulation which depressed the global price; the last U.S. mine, located in Mountain Pass, California, closed in 2002.³³

Assessments to determine the economic feasibility of rare earth mining were conducted at various sites in the U.S., and Canada in 2009.³⁴ Regardless of the outcome of these assessments, government officials estimate it could take seven or more years to bring a new domestic REE mine into production, based on a myriad of government regulations and the complexity of REE mining. Due to the diversity of REE bearing minerals, a unique processing sequence must be developed for every mine based on the specific mineral at the site.³⁵

Mines that had previously produced REE material can restart operations much more quickly than new mines. Molycorp, the owner of the existing Mountain Pass mine, indicates this mine could resume full scale production by 2012.³⁶ A monazite mine in Mont Weld, Australia began limited production in 2008 and plans to reach full production by the end of 2011. According to Stratfor Global Intelligence, these mines would account for 25—30% of global production, **if** both come into operation as projected.³⁷

Rare earth elements are seldom the sole product of a mining operation and often are a by-product of a mining effort for another mineral. As an example, REEs are a by-product of the massive iron mine in Banyan Obo, China.³⁸ The USGS estimates up to

90% of global REE production is either a co-product or by-product of a mining effort.³⁹

Mining is an expensive, capital intensive endeavor. Organizations considering developing a new mine with REE as the primary product would want security another depression in the global price would not eliminate their return on investment.

Separating & Refining The separating and refining functions are complex processes due to the nature of REE bearing minerals. Refining REE bearing ore produces by-products which are heavily regulated in the U.S. and disposal must be addressed. As an example, refining monazite produces the radioactive element thorium.⁴⁰ Since the U.S. ceased development of refining technology when the functions migrated to China, today, the refining function is considered China's strongest competitive advantage.⁴¹ Based on their ownership of the technical knowledge and infrastructure related to refining, experts expect China will retain the core of the REE industry for at least the next two to three years.

Manufacturing. Down-stream rare earth processing functions require significant capital investment. Corporations require reliable sources of supply before they will invest in downstream processing operations. Like separating and refining, advanced manufacturing technology is proprietary and much of this intellectual property is controlled by overseas companies. As an example, the technology patents a Japanese organization owns for manufacturing neodymium-boron magnets do not expire until 2014.⁴²

China's Supply Chain Strategy. China has the world's largest population and is interested in creating and protecting manufacturing and processing jobs. To achieve this goal, experts believe China is attempting to expand its' vertical integration of the

global supply chains, to include REE.⁴³ Unlike the U.S. strategy of competing for minerals on the global market, China's intent is to gain minerals it does not domestically produce through purchase of equity ownership of mineral deposits and mining companies.⁴⁴

China is incentivizing organizations to move their manufacturing functions, and associated intellectual property, to China in return for a guaranteed supply of REE material. According to industry expert Terrance Stewart, China's 2009-2015 draft mineral strategy is to macro-manage the rare earth industry, strengthen control of strategic resources and strictly control production. No new rare earth mining will be approved during this period in China.⁴⁵

Vulnerability to China

In 2009, rare earths were one of 19 non-fuel minerals for which the U.S. completely relied on imports to meet demand. According to the USGS, 91% of the REE material imported to the U.S. came from China.⁴⁶ While reliance on imported material is not a useful measure of risk; overreliance on one nation does create risk. As Dr. Kent Butts, U.S. Army War College, states:

Minerals that are required to satisfy the needs of essential sectors of the economy may be referred to as critical. When such minerals are "wholly or in a large measure imported", often through trade from non-secure overseas sources, and where the denial of access to these resources is possible to the benefit of an adversary, they may be referred to as strategic. The degree of concern expressed for a given strategic mineral is governed by the number of alternative sources from which the resource may be obtained; the political and economic stability of the producing countries; and the relative self-sufficiency of adversarial nations in the given resource.⁴⁷

The United States singular reliance on China for REE material, coupled with China's dominance of the supply chain, mark rare earths as a strategic mineral. While

China is economically and politically stable, China's words and actions regarding REE's highlight the risk to U.S. security.

China's Information Message and Actions. The Chinese government has made bold statements regarding dominating the REE industry for almost 20 years and her actions during this period have supported these statements. In 1992 Deng Xiaoping famously stated, "there is oil in the Mid-East, there is rare earth in China".⁴⁸ China's current dominance of the global REE supply chain represents the culmination of a strategic goal described by President Jiang Zemin in 1999, "improve the development and application of rare earth, and change the resource advantage into economic superiority."⁴⁹ Having driven competition out of the global market, China is now using its market dominance to gain economic superiority through manipulation of global supply and price.

China's actions over the last five years are particularly troubling. It limited the amount of rare earth material for commercial export since 2005 and most recently restricted 2010 export volume to 40% below 2009 volume. China also raised REE material export taxes by 15-25% in 2010.⁵⁰ The Chinese Ministry of Information and Technology published a draft report in the Fall of 2009 calling for a ban on exports for several varieties of REE.⁵¹ Another report in the official China Daily newspaper predicted a 30% decline in export volume in 2011. An export minister denied the newspaper report, however recent statements and actions demonstrate the potential for further restrictions.⁵²

In July 2010, China used this economic weapon as leverage in a maritime dispute when it interrupted export of REE material to Japan.⁵³ This action expanded

with a brief blockage of shipment of several REEs to the U.S. and Western Europe in October 2010. Keith Bradsher suggests this blockage may have been in retaliation to a U.S. investigation to determine whether China was violating World Trade Organization rules by limiting clean energy imports, while incentivizing clean energy exports.⁵⁴ If accurate, this speculation supports the notion that China views WTO complaints as political / strategic challenges rather than as legal actions in the world commerce structure.⁵⁵

Supply Chain Disruption Impact. The Defense Contract Management Agency's Industrial Analysis Center is preparing a report that will assess military use of rare earth materials and associated vulnerabilities based on a supply chain disruption.⁵⁶ Until this report is published, the specific impact of a supply chain disruption to DoD's security mission is speculative. Previous government reports however imply a REE restriction would cause production delays. A modeling scenario in the National Defense Stockpile 2005 Requirements Report recommended stockpiling yttrium.⁵⁷ A 2008 National Defense Stockpile report advised several production delays of weapons systems were caused by lanthanum, cerium, europium and gadolinium supply disruptions.⁵⁸ Perhaps the most clear warning is that according to the Defense Acquisition Guidebook, REEs material have reached the level of industrial concern and supplier base concerns should be investigated.⁵⁹

Long Time to Establish an Alternative Supply Chain. Some experts argue military uses are low enough that restriction of Chinese REE material will not be an issue, **if** Western mining operations come on-line.⁶⁰ While this assessment may be valid, it also implies all levels of the REE supply chain have alternatives other than

China. Mark Smith testified to a Congressional Subcommittee that if his California mine were to start production today, much of the ore would have to be shipped to China for processing.⁶¹ A 2010 GAO report advises the U.S. rare earth supply chain could take up to 15 years to rebuild based on the complexity of acquiring patents, making capital investments and developing new technology.⁶²

Increased Technology Cost. China has the ability to manipulate the global REE material price due to their dominance of the supply chain. Recent actions such as increasing export taxes and establishing export quotas for REE material increases production costs in competing countries. Increased production costs will translate into higher costs for many products. The green technology sector is particularly vulnerable to cost increases based on projected growth and the large quantity of REE material required for applications such as magnet generators.⁶³ China's supply chain dominance makes competition difficult. By artificially lowering prices, or disrupting supply, China has the ability to make REE processing unprofitable.⁶⁴

Policies, Strategies and Legislation Related to the REE Supply Chain

The vulnerability to the REE supply chain is a National issue that is being addressed by the interagency process and Congress. Broad policy goals are already established regarding strategic minerals and the industrial base. Several U.S. Government (USG) documents describe national interests and strategic objectives related to the REE issue. The DoD has statutory authority to address the REE supply chain vulnerability and the National Defense Authorization Act for Fiscal Year 2011 directs specific actions.⁶⁵ Three bills are being considered by Congress that address the rare earth supply chain vulnerability.

US Mineral Policy. The U.S. mineral policy goal is to promote an adequate, stable and reliable supply of materials for national security, economic and industrial production.⁶⁶ The Mining and Minerals Policy Act of 1970 states it is in U.S. national interest to foster a domestic mining industry.⁶⁷ Policy options to achieve the mineral policy goal include: promoting conservation of the material, encouraging domestic mining by tax policies, funding research and development to develop technology requiring alternative sources, providing incentives to promote exploration in other countries, and stockpiling strategic materials.⁶⁸

2010 National Security Strategy (NSS). The NSS directs the use of innovation and ingenuity to mitigate resource scarcity and secure our supply chains. The NSS further declares the U.S. “has a window of opportunity to lead in the development of clean energy technology. If successful, the U.S. will lead in this new Industrial Revolution in clean energy that will be a major contributor to our economic prosperity”.⁶⁹

Quadrennial Defense Review Report (QDR). The 2010 QDR states U.S. security is tied to the health of the technology and industrial bases. The QDR further states DoD requires a strategy to shape the structure and capabilities of industry and must be prepared to intervene when absolutely necessary to create and / or sustain competition, innovation and essential industrial capabilities.⁷⁰

National Defense Strategy (NDS). The 2008 NDS highlights the fact that globalization and growing economic interdependence creates vulnerabilities and that Defense policy must account for these vulnerabilities. The NDS also highlights the USG strategy regarding relations with China is to provide incentives for constructive behavior while dissuading destabilizing actions.⁷¹

Defense Industrial Policy. The Office of the Deputy Assistant Secretary of Defense for Industrial Policy (DASD- IP) manages industrial base issues for DoD. Industrial Policy works to sustain an environment that ensures the industrial base is reliable, cost-effective, and sufficient to meet DoD requirements.⁷² Because rare earth based or enhanced applications are typically far upstream, monitoring all their applications and sources of supply is difficult. If a vulnerability is identified, DASD-IP can recommend stockpiling material in the National Defense Stockpile (NDS) and / or the employment of the Defense Production Act (DPA) to spur industrial production.⁷³

The best option to mitigate the threat of a mineral import cut-off is the NDS, a collection of critical or strategic materials stockpiled and managed by the Defense Logistics Agency.⁷⁴ The NDS is maintained in order to reduce the possibility of “a dangerous and costly dependence by the U.S. upon foreign sources for supplies of such materials in times of national emergency.”⁷⁵ The recommendation to stockpile is coordinated thru the interagency process.⁷⁶ Rare earth material could be acquired at various levels of the supply chain if the decision is made to stockpile.

The Defense Production Act provides DoD statutory authority to intervene domestically if required to support national security requirements. Title III of the Act allows the USG to provide financial incentives to create, modernize or expand industrial capacity. Financial incentives that could be applied include: purchase and installation of production equipment, establishment of a guaranteed market to expand or maintain production, loans or loan guarantees or, funding for development of substitutes. The DoD can also enter into a non-binding arrangement known as a Security of Supply with a foreign partner to provide reciprocal material support.⁷⁷ Title I of the DPA also allows

for prioritization of government contracts. While employment of this Act is a drastic measure, it was used extensively in support of the Global War on Terror.

National Defense Authorization Act for Fiscal Year 2011 – H.R. 6523. Critical components of H.R. 6523 include direction for the Secretary of Defense to: conduct an immediate review of DoD rare earth requirements, establish an “assured source of supply” of rare earth material by 2015 and, consider establishing a stockpile.⁷⁸ H.R. 6523 became public law January 7, 2011.⁷⁹

Rare Earth and Critical Materials Revitalization Act of 2010 – H.R. 6160. Critical components of H.R. 6160 include direction for the Secretary of Energy to: expand research and development of REE technology, make loan guarantee commitments for the commercial application of new or significantly improved rare earth supply chain technology, and, work with private sector participants to make a complete REE materials production capability in the U.S. within five years. H.R. 6160 was approved in the House and referred to the Senate September 29, 2010.⁸⁰

Rare Earths Supply Technology and Resources Transformation Act of 2010 – S. 3521. Critical components of S 3521 include: creation of a task force to expedite review and approval of permits related to development of a domestic REE capability, direction for the Secretary of Energy to issue guidance regarding obtaining REE industry federal loan guarantees, and, direction for the Secretary of Defense to report on past, current and future projects to support the domestic rare earth supply chain. Hearings were conducted on S. 3521 September 30, 2010.⁸¹

Rare Earths Supply-Chain Technology and Resources Transformation Act of 2010 – H.R. 4866. Critical components of H.R. 4866 include: creation of an interagency

working group to determine which rare earths are critical to national and economic security, direction for the Secretary of Defense to procure and stockpile critical rare earths, instruction for the U.S. Trade Representative to report to Congress on international trade practices in the rare earth market, and, direction for the Secretaries of Defense and Energy to issue guidance related to obtaining loan guarantees, expressing the sense of Congress regarding appropriation of the Defense Production Act to develop the rare earth supply chain. Hearings were last conducted March 17, 2010 on HR 4866.⁸²

Other Interests Impacting the REE Supply Chain

Environmental Interests. Environmental interests significantly influence the REE supply chain and present a problematic dichotomy. As highlighted, the desire to move to clean technology is a major factor driving the increase of global REE demand. This demand results in increased REE mining, separating and refining; which are all decidedly un-environmentally friendly processes. Mitigation measures often require improved procedures or technology.⁸³

Nineteen Federal Acts and regulations promulgate environmental legal requirements for mining operations. Compliance often requires added expense.⁸⁴ As an example, Senate committee hearings were conducted in 2009 to consider the *Hardrock Mining and Reclamation Act S796*. While not ratified, this Bill would have subjected production of relocateable minerals to a 2-5% royalty on the gross income from mining.⁸⁵ Environmental laws and regulations are also established at the state level. China has begun enforcement of environmental laws which is expected to contribute to reduced production.⁸⁶

Economic Interests. National security is built on economic well being. One of the leading concerns regarding the health of the U.S. economy is the size of the national debt, which has exploded to over \$14.2 trillion.⁸⁷ Many call for reducing federal spending to lessen the debt. Government willingness to fund development of a domestic rare earth supply chain and / or acquire a rare earth material stockpile is uncertain. Recent practice has been to generate income thru sales of stockpile assets vice acquiring more material.⁸⁸

The U.S. and China's economies are closely intertwined and many agree it is in both countries interest for each to be economically healthy. China is the largest holder of U.S. debt with approximately \$1.7 trillion in holdings.⁸⁹ China is also one of the U.S.'s largest trading partners and the REE supply chain situation is one of many trade issues between the nations.

The U.S. is the global leader in technology and innovation and is competing with China for high technology jobs.⁹⁰ Development of a high technology rare earth processing chain could spur domestic job creation in the green technology and advanced manufacturing sectors. Protection of U.S. innovation and intellectual property is critical to meeting U.S. economic goals and is significant issue in U.S. – China economic relations, as highlighted by U.S. Secretary of State Hillary Rodham Clinton:

If the United States does not once again become the leading innovation nation, it's hard to know where we're going to find the jobs that we have to produce for people. And yet if we do it wrong, or we do it artificially as in some countries are in my view doing that will lead to protectionism. We had a very frank conversation led by Secretary Geithner, with our Chinese friends in Beijing. They see a very stark problem. They have tens of millions of people they're still trying to get out of absolute poverty, so they want to have an innovation agenda that would in effect capture company's intellectual property and require companies to operate inside China in a way that could undermine the long-term success of those companies. So

we say no, that's not a good way to do it. But the debate about how to do this is going to be front and center of international economic dialogue.⁹¹

Recommendation

The DoD should employ an integrated supply chain strategy, supported by all elements of National Power, to ensure the REE industrial base remains reliable, cost-effective, and sufficient to meet National Security requirements. This strategy would be aligned with leveraging of public and private sector ingenuity to secure our supply chains and would support development of clean technology to enhance economic prosperity.

Validate Requirements and Supply Chains. To develop an effective strategy to mitigate the supply chain risk, DASD-IP must understand: what military weapons and systems contain REE applications, what supporting supply chains are vulnerable to a disruption, and, where in the supporting supply chain is the disruption most likely to occur. Prior to direction by Congress, DASD-IP proactively initiated development of a report to assess the REE supply chain vulnerabilities.⁹² The results of this report, coupled with the comprehensive review of DoD requirements mandated by the 2011 National Defense Authorization Act, will serve as the basis for future actions.

Stockpile. Results of the DASD-IP assessment and investigation into supplier base concerns, will dictate whether DASD-IP recommends stockpiling REE material. If a supply chain vulnerability is identified to a critical weapon or system that could impact National Security, REE material should be stockpiled. Stockpiling offers a comparatively quick way to mitigate the REE supply chain vulnerability. Because there are significant REE reserves in the U.S. and other friendly nations, stockpiling does not

have to be a long term endeavor. Once a more secure supply chain is developed, the stocks should be assessed for potential resale on the global economy.

Japan is a major consumer of REE materials and her actions to confront a similar REE supply chain vulnerability are instructive. Japan anticipated a REE supply disruption and stockpiled material to mitigate production disruptions prior to the Chinese embargo.⁹³ Japan is also now establishing sources in other countries, to include Australia and Vietnam, as well as conducting R&D for REEs substitutes.⁹⁴

Develop an Integrated Supply Chain. The source of China's economic power related to REE material comes from their complete dominance of the global supply chain. Diversifying and integrating the REE supply chain will reduce China's ability to restrict material flow and control the market price.

Foster Domestic Processing. As described in the QDR, DASD-IP should shape the structure and capabilities of the domestic REE industry to develop an assured source of supply by 2015, as mandated by Congress. Incentivization should focus on specific supply chain vulnerabilities related to DoD applications, such as manufacturing of neodymium-boron magnets. The DoD should use Title III of the DPA to offer loan guarantees for capital and technology investment and guarantee procurement levels of critical applications to incentivize processing.

The DoD effort would complement a broader USG strategy, developed through the interagency process and Congress, of fostering a domestic REE supply chain. As David Sandalow, Department of Energy - Assistant Secretary for International Affairs stated regarding REEs, "reopening domestic production is an important part of a globalized supply chain."⁹⁵ Critical components of this strategy are support for domestic

REE mining and support for R&D of rare earth alternatives and processing technology. The three bills being considered by Congress provide useful measures to enable this strategy.

The USG should immediately incentivize domestic mining in order to stabilize the supply chain base and provide organizations security to invest in down-stream functions. This action would reverse current government practices as demonstrated by the DoE's denial of Molycorp's request for a guaranteed loan for capital equipment in 2009. The DoE denied the request because mining was considered too far upstream in the supply chain.⁹⁶

The USG should spur R&D for processing technology and alternatives to developing an integrated, secure supply chain. Advanced processing techniques enable industry to meet stringent environmental regulations and gain a competitive market advantage. Steve Duclos, the Director of G.E. Global Research, testified "Corporations will seek to develop alternative materials if they expect an economic advantage or if they foresee a supply constraint. The Federal Government can help by enabling public-private collaborations that provide both the materials understanding and the resources to attempt the higher risk approaches."⁹⁷

International Processing. The USG should promote supply chain integration with reliable partners such as Canada and Australia that does not conflict with efforts to foster a domestic supply chain. Integrating the supply chain will increase security by promoting international cooperation based on mutual interests. DoD should also establish Security of Supply agreements with foreign partners that possess required REE material to increase assurance of supply.

Shaping the International Environment.

All elements of National Power should be employed to shape the international environment for successful development of an integrated REE supply chain.

Diplomatic Power. Diplomats should work to strengthen ties with China in areas of mutual interest and strengthen relationships with other REE producing nations. By strengthening ties in areas of common interest, China may be less likely to act irresponsibly regarding REE material. Soft power should be applied to persuade other nations to resist China's attempts to establish bi-lateral relations to further vertical integration.

Information Power. The U.S. information campaign towards China should consistently reinforce two messages: (1) our economies are mutually supporting with room for both to be successful, and, (2) China must behave responsibly in the international environment to be treated as a world leader. Information power can be employed against "heavy handed" actions such as stealing intellectual property and placing an REE material embargo on Japan. Robert Suettinger, China specialist and former senior policy analyst at RAND, states, "Public opinion is increasingly effective as a means of affecting Chinese behavior. That involves both international opinion – shaming, exposing human rights abuses, calling into doubt Chinese sincerity, can be useful ways of improving compliance..."⁹⁸

Military Power. Retaining American military presence in the Asia-Pacific region is critical to maintaining relationships that provide the foundation for economic security and progress. As an example, the U.S. relationship with Australia, who possesses large REE reserves, is enhanced by military cooperation.

Economic Power. The United States must carefully employ economic power to meet China's REE material challenge. The U.S. should include the REE situation in broader economic discussions with China. Due to the size of the U.S. debt to China, trade actions and WTO protests have limited value. The U.S. can also incentivize REE production in countries other than China through tax policies. This action must be approached cautiously so it does not conflict with initiatives to foster a domestic supply chain.

Conclusion

REE applications are critical to technically advanced U.S. military weapons and systems, and for several green technologies. China's dominance of the REE supply chain and recent willingness to use REE material as an economic weapon create a clear and present vulnerability to National Security. To mitigate this risk, DoD should foster development of an integrated REE supply chain. This strategy, supported by all elements of national power, will ensure the REE industrial base is sufficient, reliable and cost efficient to support DoD requirements.

Endnotes

¹ Mark A. Smith, "Rare Earth Minerals," U.S. Congress, House Science and Technology Committee, Subcommittee on Investigation and Oversight, *Congressional Quarterly*, March 16, 2010, 4.

² U.S. Government Accountability Office, *Rare Earth Materials in the Defense Supply Chain, Briefing for Congressional Committees* (Washington, DC: U.S. Government Accountability Office, April 2010), 20.

³ Keith Bradsher, "Pentagon Must 'Buy American,' Barring Chinese Solar Panels, The New York Times, January 10, 2011, <http://www.nytimes.com/2011/01/10/business/global/10solar.html> (accessed January 15, 2011).

⁴ Barack Obama, *National Security Strategy* (Washington, DC: The White House, May 2010), 31.

⁵ Mark Humphries, *Rare Earth Elements: The Global Supply Chain*, Congressional Research Service, (Washington, DC, September 30, 2010), 1.

⁶ C.K. Gupta and N. Krishnamurthy, *Extractive Metallurgy of Rare Earths* (Boca Raton, FL: CRC Press, 2005) 1, 61, 59.

⁷ Gupta and Krishnamurthy, *Extractive Metallurgy of Rare Earths*, 21, 22, 32; Cindy A. Hurst, "China's Ace in the Hole: Rare Earth Elements," *Joint Forces Quarterly Issue* 59 (4th Qtr 2010), 123.

⁸ Mark A. Smith, "Rare Earth Minerals," 4.

⁹ U.S. Geological Survey, *Mineral Commodity Summaries - 2010* (Washington, DC: U.S. Government Printing Office, 2010), 128.

¹⁰ Gupta and Krishnamurthy, *Extractive Metallurgy of Rare Earths*, 9-15, 30-32.

¹¹ James B. Hedrick, U.S. Geological Survey, "Rare Earths in Selected U.S. Defense Applications", 40th Forum on the Geology of Industrial Minerals, Bloomington, Indiana, May 2-7, 2005.

¹² Mark A. Smith, "Rare Earth Minerals," 4; Gupta and Krishnamurthy, *Extractive Metallurgy of Rare Earths*, 30-32.

¹³ Mark A. Smith, "Rare Earth Minerals," 4.

¹⁴ Hurst, "China's Ace in the Hole: Rare Earth Elements," 124, 125.

¹⁵ U.S. Geological Survey, *Mineral Commodity Summaries - 2010*, 129.

¹⁶ U.S. Government Accountability Office, *Rare Earth Materials in the Defense Supply Chain, Briefing for Congressional Committees*, 27.

¹⁷ Ibid, 24.

¹⁸ Gupta and Krishnamurthy, *Extractive Metallurgy of Rare Earths*, 57.

¹⁹ Ibid, 69-70.

²⁰ U.S. Geological Survey, *The Principle Rare Earth Elements Deposits of the United States – A Summary of Domestic Deposits and a Global Perspective*, Scientific Investigations Report 2010-5220 (Reston, Virginia: 2010) 10-11.

²¹ Ibid, 15.

²² U.S. Geological Survey, *Mineral Commodity Summaries - 2010*, 129.

²³ U.S. Geological Survey, *The Principle Rare Earth Elements Deposits of the United States – A Summary of Domestic Deposits and a Global Perspective*, 7.

²⁴ U.S. Geological Survey, *Mineral Commodity Summaries - 2010*, 128.

²⁵ *Rare Earths Supply, Technology and Resource Transformation Act of 2010* – S. 3521, Section 2. Findings. LexisNexis Congressional (accessed November 24, 2010).

²⁶ Mark Humphries, *Rare Earth Elements: The Global Supply Chain*, 3.

²⁷ U.S. Geological Survey, *Mineral Commodity Summaries - 2010*, 129.

²⁸ Robin Bromby, “Caution, Rare Earths Ahead”, April 26, 2010, linked from *The Australian*, <http://www.theaustralian.com.au/business/mining-energy/caution-rare-earths-ahead> (accessed December 3, 2010).

²⁹ Keith Bradsher, “Earth Friendly Elements; Mined Destructively” Dec 26, 2009, linked from The New York Times, <http://www.nytimes.com/2009/12/26/business/global/26rare.html> (accessed January 7, 2011).

³⁰ Mark A. Smith, “Rare Earth Minerals,” 4.

³¹ U.S. Government Accountability Office, *Rare Earth Materials in the Defense Supply Chain*, 19.

³² U.S. Geological Survey, *Mineral Commodity Summaries - 2010*, 129.

³³ “No.22 Rare Earth Elements: A Wrench in the Supply Chain?” Center for Strategic & International Studies, Current Issues (Washington, DC: Defense Industrial Initiatives Group, October 5, 2010).

³⁴ U.S. Geological Survey, *Mineral Commodity Summaries - 2010*, 129.

³⁵ U.S. Geological Survey, *The Principle Rare Earth Elements Deposits of the United States – A Summary of Domestic Deposits and a Global Perspective*, 21, 7.

³⁶ U.S. Government Accountability Office, *Rare Earth Materials in the Defense Supply Chain*, 18.

³⁷ STRATFOR Global Intelligence, “Special Report: China and the Future of Rare Earth Elements,” (Oct 12, 2010): 3.

³⁸ Gupta and Krishnamurthy, *Extractive Metallurgy of Rare Earths*, 94.

³⁹ U.S. Government Accountability Office, *Rare Earth Materials in the Defense Supply Chain*, 11.

⁴⁰ U.S. Geological Survey, *The Principle Rare Earth Elements Deposits of the United States – A Summary of Domestic Deposits and a Global Perspective*, 7.

⁴¹ STRATFOR Global Intelligence, Special Report, “China and the Future of Rare Earth Elements,” 4, 5.

⁴² U.S. Government Accountability Office, *Rare Earth Materials in the Defense Supply Chain, Briefing to Congressional Committees*, 24.

⁴³ Terence P. Stewart Testimony, “Rare Earth Materials,” U.S. Congress, House Science and Technology Committee, Subcommittee on Investigation and Oversight, *Congressional Quarterly*, March 16, 2010; Mark Humphries, *Rare Earth Elements: The Global Supply Chain*, 9.

⁴⁴ Kent H. Butts & Brent Bankus, “China and Natural Resource Competition” in *Understanding Africa: A Geographic Approach*, (West Point, NY: United States Military Academy) 349.

⁴⁵ Terence P. Stewart Testimony, “Rare Earth Materials,” U.S. Congress, House Science and Technology Committee, Subcommittee on Investigation and Oversight, *Congressional Quarterly*, March 16, 2010.

⁴⁶ U.S. Geological Survey, *Mineral Commodity Summaries – 2010*: 6, 128.

⁴⁷ Kenneth H. Butts, *Strategic Minerals in the New World Order*, (Carlisle, PA: Strategic Studies Institute, US Army War College, 1993), 11.

⁴⁸ Jianjun Tu, “An Economic Assessment of China’s Rare Earth Policy,” The Jamestown Foundation, November 8, 2010, http://www.jamestown.org/programs/chinabrief/single/?tx_ttnews%5Btt_news%5D=37141&tx_ttnews%5BbackPid%5D=414&no_cache=1 (accessed November 12, 2010).

⁴⁹ Hurst, “China’s Ace in the Hole: Rare Earth Elements,” 124; Tu, *An Economic Assessment of China’s Rare Earth Policy*, 2.

⁵⁰ “No.22: Rare Earth Elements: A Wrench in the Supply Chain?” October 5, 2010.

⁵¹ NYTimes webpage, “Canadian Firm Steps Up Search for Rare Earth Metals”, September 9, 2009, <http://www.nytimes.com/2009/09/10/business/global/10mineral.html> (accessed January 29, 2011).

⁵² Keith Bradsher, “China Said to Widen its Embargo of Minerals”, The New York Times, October 19, 2010 <http://www.nytimes.com/2010/10/20/business/global/20rare.html> (accessed January 13, 2011).

⁵³ Paul Krugman, “Rare and Foolish”, The New York Times, October 1, 2010 <http://www.nytimes.com/2010/10/18/opinion/18krugman.html> (accessed 15 Jan 2011).

⁵⁴ Keith Bradsher, “China Said to Widen its Embargo of Minerals”, The New York Times, October 19, 2010 <http://www.nytimes.com/2010/10/20/business/global/20rare.html> (accessed 13 Jan 2011).

⁵⁵ C. Fred Bergsten et al, *China’s Rise: Challenges and Opportunities* (Washington DC: Peterson Institute for International Economics, September 2008), 225.

⁵⁶ Defense Contract Management Agency Industrial Analysis Center Study Plan, *Rare Earths Materials (Lanthanoids) Assessment* (2010).

⁵⁷ Scott F. Romans, *The Role of the National Defense Stockpile in the Supply of Strategic and Critical Materials*, Strategy Research Project (Carlisle Barracks, PA: U.S. Army War College, 9 May, 2009), 14.

⁵⁸ U.S. Government Accountability Office, *Rare Earth Materials in the Defense Supply Chain, Briefing to Congressional Committees*, 31.

⁵⁹ "No.22 Rare Earth Elements: A Wrench in the Supply Chain?" October 5, 2010.

⁶⁰ Hurst, "China's Ace in the Hole: Rare Earth Elements,"124.

⁶¹ Mark A. Smith, "Rare Earth Minerals," 5.

⁶² U.S. Government Accountability Office, *Rare Earth Materials in the Defense Supply Chain, Briefing to Congressional Committees*, 13.

⁶³ STRATFOR Global Intelligence, "Special Report: China and the Future of Rare Earth Elements," 5-7.

⁶⁴ Tu, "*An Economic Assessment of China's Rare Earth Policy*", 2.

⁶⁵ H.R. 6523, "Ike Skelton National Defense Authorization Act for Fiscal Year 2011" <http://www.gpo.gov/fdsys/pkg/BILLS-111hr6523enr/pdf/BILLS-111hr6523enr.pdf> (accessed January 15, 2010) 28.

⁶⁶ Mark Humphries, *Rare Earth Elements: The Global Supply Chain*, 1.

⁶⁷ Kathleen Clark, Policy Statement, Bureau of Land Management-Energy and Non-Energy Mineral Policy, April 21, 2006, http://www.nma.org/pdf/072606_blm.pdf (accessed January 15, 2011).

⁶⁸ Butts, *Strategic Minerals in the New World Order*, ix-xi.

⁶⁹ Barack Obama, *National Security Strategy*, 31, 30.

⁷⁰ Robert M. Gates, *Quadrennial Defense Review Report* (Washington DC: 1000 Defense Pentagon, February 2010), xv, 81.

⁷¹ Robert M. Gates, *National Defense Strategy* (Washington DC: 1000 Defense Pentagon, June 2008), 4, 5, 11.

⁷² Deputy Assistant Secretary of Defense - Industrial Policy Home Page, <http://www.acq.osd.mil/ip/about.shtml> (accessed January 15, 2011).

⁷³ David A. Cammarota, Office of Secretary of Defense - Industrial Policy, interview by author, November 24, 2010.

⁷⁴ Butts, *Strategic Minerals in the New World Order*, xi.

⁷⁵ Romans, *The Role of the National Defense Stockpile in the Supply of Strategic and Critical Minerals*, 1.

⁷⁶ Cammarota, interview by author, November 24, 2010.

⁷⁷ Deputy Assistant Secretary of Defense, Industrial Policy Home Page, The Defense Production Act, January 20, 2010, <http://www.acq.osd.mil/ip/about.shtml> (accessed January 15, 2011). 22, 28, 42, 37.

⁷⁸ Keith Bradsher, "Pentagon Must 'Buy American,' Barring Chinese Solar Panels", The New York Times, January 10, 2011, <http://www.nytimes.com/2011/01/10/business/global/10solar.html> (accessed January 15, 2011).

⁷⁹ Library of Congress Home Page, <http://thomas.loc.gov/cgi-bin/bdquery/z?d111:H.R.6523>: (accessed January 15, 2011).

⁸⁰ *Rare Earths and Critical Materials Revitalization Act of 2010 - H.R. 6160*, LexisNexis Congressional (accessed November 24, 2010).

⁸¹ *Rare Earths Supply, Technology and Resource Transformation Act of 2010 – S. 3521*, LexisNexis Congressional (accessed November 24, 2010).

⁸² *Rare Earths Supply, Technology and Resource Transformation Act of 2010 – H.R. 4866*, LexisNexis Congressional (accessed November 24, 2010).

⁸³ Mark A. Smith, "Rare Earth Minerals," 6. "No.22 Rare Earth Elements: A Wrench in the Supply Chain?" Center for Strategic & International Studies, Current Issues (Washington, DC: Defense Industrial Initiatives Group, October 5, 2010).

⁸⁴ National Mining Association, "Mining and Environmental Stewardship", http://www.nma.org/pdf/fact_sheets/env.pdf (accessed January 15, 2011).

⁸⁵ S 796 Hardrock mining and Reclamation Act of 2009, Govtrack website, <http://www.govtrack.us/congress/bill.xpd?bill=s111-796> (accessed January 29, 2011).

⁸⁶ Leslie Hook, "China reins in rare earth exports," Financial Times online, October 19, 2011, <http://www.ft.com/cms/s/0/ae49b354-dba7-11df-a1df-00144feabdc0.html#axzz1B9wjBnyE> (accessed January 15, 2011).

⁸⁷ U.S. Debt Clock.org website, January 15, 2011, <http://www.usdebtclock.org/#> (accessed January 15, 2011).

⁸⁸ Romans, *The Role of the National Defense Stockpile in the Supply of Strategic and Critical Materials*, 6.

⁸⁹ The Washington Times, March 2, 2010 "China holds more U.S. debt than indicated," <http://www.washingtontimes.com/news/2010/mar/02/chinas-debt-to-us-treasury-more-than-indicated/> (accessed January 15, 2010).

⁹⁰ BloombergBusinessWeek “Why America Needs an Economic Strategy,” October 30, 2008, http://www.businessweek.com/magazine/content/08_45/b4107038217112.htm (accessed November 13, 2011).

⁹¹ Hillary R. Clinton, “Remarks on the Obama Administration’s National Security Strategy” May 27, 2010 <http://www.state.gov/secretary/rm/2010/05/142312.htm> (accessed November 13, 2010).

⁹² Cammarota, interview by author, November 24, 2010.

⁹³ Keith Bradsher, “China Said to Resume Shipments of Rare Earth Materials”, The NYTimes.com, October 28, 2010. <http://www.nytimes.com/2010/10/29/business/energy-environment/29rare.html> (accessed January 29, 2011).

⁹⁴ Wall Street Journal digital network, “Might the Prius one day get a digital heart?” September 4, 2009. <http://blogs.wsj.com/chinarealtime/2009/09/04/might-the-prius-one-day-get-a-chinese-heart/> (accessed January 15, 2011); STRATFOR Global Intelligence, “Special Report: China and the Future of Rare Earth Elements,” 6.

⁹⁵ Guardian UK website, December 26, 2010, “Rare Earths Metal Mine is Key to US Control Over High Tech Future”, <http://www.guardian.co.uk/environment/2010/dec/26/rare-earth-metals-us> (accessed January 29, 2011).

⁹⁶ Mark A. Smtih Testimony, “Rare Earth Minerals and 21st Century Industry,” March 16, 2010.

⁹⁷ Steven J. Duclos, Chief Scientist and Manager, GE Global Research, “Rare Earth Minerals” Testimony to U.S. Congress, House Science and Technology Committee, Subcommittee on Investigation and Oversight, March 16, 2010, LexisNexis.com <http://weblexis-nexis.com/congcomp/document> (accessed October 25, 2010).

⁹⁸ Robert Suettinger “U.S. China Policy: The Importance of Debate” in *Economics & National Security: The Case of China*, editors Kent H. Butts and Edward L. Hughes (Carlisle, PA: Center for Strategic Leadership, 2002) 392.